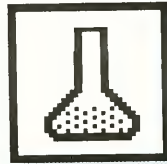




Alternative Fuels Briefing Report



**prepared by the
Regional Transportation Authority**

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EXECUTIVE SUMMARY

Current local and national requirements on air quality as well as the U.S. energy policy could alter the region's fuel needs, require changes in existing facilities and require a considerable investment of capital and operating funds in the next three to four years. These requirements will impact the RTA in three areas:

- **New Technology:** Modifications to existing or new engines, fuel handling and storage, and vehicle design will be required.
- **Economic Cost Impact:** Research has shown that any change will negatively impact current RTA operating and capital expenses.
- **Market Opportunities:** The push for improved air quality could have the beneficial impact of increasing demand for public transit. This report, however, does not consider that possibility.

This report is designed to provide a review of the policy issues concerning fuels, give an overview of the subject and analyze alternative fuel options available to the RTA and its Service Boards.

A major objective of this report is to make the RTA Board aware of the costs associated with meeting the new E.P.A. regulations while complying with national energy policy. The report examines the various risks and benefits associated with the alternatives so that the Board can make informed decisions on policy.

Policy Issues

The current emphasis on alternative fuels is driven by national energy policy as well as environmental concerns. The combination of these concerns yield differing results than considered separately.

Current environmental concerns are aimed at reducing three types of pollution: ground level ozone or "smog," "greenhouse effect," and acid rain. Efforts to curb urban air pollution center on reducing the production of ground level ozone, the major pollution problem in metropolitan areas.

Since vehicle emissions are a major contributor to urban air pollution, the E.P.A. is now requiring that buses manufactured after December 31, 1990 meet new stricter engine emission standards. The goal of these standards is to reduce ground level ozone by significantly decreasing nitrogen oxide and particulate emissions. These new emissions standards require either modifications to diesel buses or the introduction of another, alternative fuel source.

It is likely, however, that these E.P.A. regulations will change when Congress considers the amendment to the Clean Air Act. The Administration's current proposal delays implementation of the new stricter emissions standards until 1994 but requires a phasing in of alternative fueled vehicles beginning in 1991.

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Another important factor included in the Administration's proposal calls for a portion of passenger cars manufactured in 1994 to be alternatively fueled. Since the total transportation industry consumes 62% of all petroleum uses compared to the transit industry which consumes less than 0.5% of all petroleum uses, this will have a significant impact on the availability and price of the various alternative fuels.

Another aspect of Federal policy focuses on decreasing U.S. dependence on foreign fuels, particularly petroleum, as well as U.S. dependence on a diminishing supply of fossil fuels. During the energy crisis of the mid seventies it became clear that dependence on foreign sources was undesirable from a national security standpoint. U.S. dependence on fossil fuels, estimated at over 75% by 2010, has led to similar concerns regarding a stable long term fuel supply for the U.S.

Clearly, compliance with both of these policies would require the transit industry to move toward the use of alternative fuels. The alternative fuels that can currently meet the E.P.A. regulations and move the transit industry away from dependence on foreign petroleum are: ethanol, methanol, and compressed natural gas (CNG). Since methanol and CNG are both fossil fuels it is likely that the U.S. will be trading dependence on one fossil fuel for another given the options currently available. However, it is likely that CNG requirements could be met from domestic supplies.

Fuel Characteristics

This study considered the fuel characteristics because they vary considerably from diesel. This variability has a major impact on handling and storage of fuel as well as the engine and garage design and the cost of engine maintenance.

Diesel, the common name for a #1 or #2 fuel oil, is the primary fuel used in heavy duty engines. It is refined from crude oil, is flammable, and contains numerous toxic compounds. Emissions from current diesel engines which are equipped with electronic controls and oxidizers, using the least polluting grade of diesel, do not meet 1991 E.P.A. requirements.

Compressed natural gas (CNG) is natural gas used at a very high pressure, 3,000 psi (pounds per square inch) versus .22 psi gas used for home cooking purposes. Since this fuel is a gas, rather than liquid, the use of CNG in buses would substantially change the storage, fueling and maintenance requirements for the transit industry. Emissions from CNG engines meet 1991 E.P.A. emissions standards.

Methanol, more commonly called "wood alcohol," is an alcohol made from natural gas, wood or coal. It is highly toxic; drinking two ounces can be fatal. Currently the preferred alternative fuel of the E.P.A., methanol is less polluting than diesel and meets 1991 E.P.A. emissions standards with the possible exception of aldehyde emissions. Aldehyde toxicity could be very expensive to control in a closed area such as bus garages. Also, methanol's corrosiveness increases engine wear and maintenance costs.

Ethanol is a renewable fuel manufactured from corn, sugar and other starches. It is too expensive to use in a pure form but, blended with gasoline to form gasohol, is the primary non-fossil alternative motor fuel in the U.S. today. No ethanol engine has been developed. Ethanol has been tested on methanol engines and meets 1991 E.P.A. emission standards.

Fuel Availability

As long as alternative fuel use is limited to the transit industry the long term availability, supply and price of the various options is unaffected by the addition of transit use. However, if the Clean Air Act is amended to include cars, as is proposed, there would be a major impact on fuel availability, supply and price since vehicles account for 62% of all petroleum uses. This would affect the economics of alternative fuel usage for the transit industry.

Switching to an alternative fuel source also changes the transit industry's dependence from the oil industry to a public utility in the case of compressed natural gas, the chemical industry for methanol and the agricultural processing industry for ethanol. In all three cases price, availability and supply would be substantially affected.

Technology/Costs

This study focused on the technological aspects of meeting the environmental standards and the costs associated with these technologies. These technologies are still at the developmental stage; therefore, the cost effectiveness and availability of technical options to meet emission standards is changing and will continue to be refined during the next three years.

The technology to modify diesel engines so that they can meet current emission standards is nearly available. Its development, however, has been slowed because current E.P.A. regulations do not require that truck heavy duty engines meet the stricter emission requirements until 1994. Trucks and buses both use heavy duty diesel engines, with trucks accounting for 99% of the market. Engine manufacturers are fairly confident that they can develop diesel technology to meet the stricter E.P.A. emission requirements, however, their development is targeted toward 1994 implementation. This gap causes problems for transit since the stricter E.P.A. emission requirements apply to transit in 1991. While modified diesel technology will be more expensive than current technology, the incremental costs of conversion will be insignificant when compared to the costs of converting to an alternative fuel.

Ethanol engines have not been developed because this fuel is four times as expensive as diesel. Ethanol tests have been limited to injection systems. Injection systems introduce a small amount of a cleaner burning alternative fuel like ethanol to the fuel stream prior to entering the combustion chamber.

Cummins Engine Co. has developed a dedicated CNG engine but it has not been demonstrated. Less than 100 of these engines will be in operation by next year, and their efficiency and reliability are not known. Detroit Diesel has been testing a methanol engine but, again, its reliability and efficiency are not known.

Conversion to any alternative fuel will require large increases in both capital and operating costs. RTA staff estimated that it would require an additional investment of \$15,000 per bus and \$4.6 million per garage for CNG and an additional \$20,000 per bus and \$5.6 million per garage for methanol to purchase alternatively fueled buses and to convert the garages and maintenance shops to handle the new fuel and engines. In addition, operating costs, mostly higher fuel and maintenance costs, would increase the annual operating budget by \$25-50 million the next ten years. Also, conversion to CNG or methanol provides certain perceived safety risks. In the case of methanol, the down side is the high level of aldehyde emissions which have known harmful human health effects.

Conclusions

The current push by the federal government to move quickly to alternative fuels presents two dilemmas to the transit industry.

- The technologies for alternative fuels have not been developed and mass production of engines has not taken place. As a result there are numerous uncertainties concerning the operating efficiencies and reliabilities of new engines and the amount of support they may need.
- The E.P.A. emission requirements are likely to be met by 1994 using diesel, with modifications to the existing diesel engine. This approach would allow compliance with environmental regulations, but would not meet the federal government's objective of moving away from dependence on foreign petroleum.

A clear choice as to which technology and fuel is more desirable has not emerged even though numerous demonstrations with alternative fueled buses have taken place. The four major reasons for this uncertain outlook are: adequacy of gas and oil reserves; international, political and technical unknowns. Our current research shows that CNG is marginally more desirable, from an environmental and financial perspective, than other alternative fuels.

Recommendations

The RTA recommendations are:

- I. Delay a decision on the consideration of fuel conversion until:
 1. Solutions to the safety aspects of these fuels are further developed;
 2. Suppliers of alternative fuels develop plans that will provide sufficient fuel supplies at reasonable costs;
 3. Engine manufacturers develop a better, more efficient engine to handle alternative fuels; and
 4. A New Clean Air Act is adopted by Congress.
- II. Continue to cooperate and work together with fuel suppliers, engine manufacturers and other government agencies to refine the cost and improve technology. Specific steps the RTA should take are:
 1. Share the results of our research with the Service Boards;
 2. Continue to communicate with other transit agencies around the country who are doing actual demonstrations, and refine the costs. Monitor and evaluate new and emerging technologies.

3. Work with CNG suppliers in the region to get better estimates of the cost to convert to natural gas.
 4. Work with the Service Boards to determine specific concerns which could be addressed by a demonstration of alternative fuels and, if warranted, develop a demonstration for either an alternative fuel or new generation of diesel engine and/or diesel fuel.
 5. Reserve sufficient funds to implement a demonstration in late 1990 if warranted.
- III. Focus lobbying efforts to make the use of alternative fuels optional **not** mandatory.

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INTRODUCTION

Current local and national requirements on air quality as well as the U.S. energy policy could alter the region's fuel needs, require changes in existing infrastructure and require a considerable investment of scarce capital and operating funds in the next three to four years. These requirements will impact the RTA in three areas:

- **New Technology:** Modifications to existing or new engines, fuel handling and storage, etc. will be required.
- **Economic Cost Impact:** Research has shown that any change will negatively impact RTA operating and capital expenses.
- **Market Opportunities:** The push for improved air quality could have the beneficial impact of increased demand for public transit. This report does not cover this aspect since it is more appropriately dealt with in the development of a long range plan.

This report is designed to provide a review of the policy issues concerning fuels, give an overview of the subject and analyze alternative fuel options available to the RTA and its Service Boards.

A major objective of this report is to make the RTA Board aware of the costs associated with meeting the new E.P.A. regulations while complying with national energy policy. The report examines the various risks associated with the alternatives so that the Board can make calculated decisions on policy.

POLICY ISSUES

Air Pollution Standards

The federal government has implemented clean air standards for U.S. cities since passage of the Clean Air Act in 1970. Major metropolitan areas such as Chicago have routinely failed to comply with the regulations. The declining air quality has led to several legislative initiatives to curb urban air pollution. Efforts to curb urban air pollution center on reducing the production of ground level ozone, the major pollution problem in metropolitan areas. Ground level ozone is a precursor to smog.

Ground level ozone should not be confused with changes in the earth's upper atmospheric layer, the "greenhouse effect". Ground level ozone is produced from emissions of volatile chemicals from cars, factories and other sources which chemically react with the sun. This type of ozone is a form of oxygen that contributes to respiratory and other illnesses. Ground level ozone is usually localized but can be blown several miles from its source and become a regional problem. Efforts to curb ground level ozone are aimed at metropolitan areas and surrounding communities.

The "greenhouse effect," says that the earth may be warming due to gases in the atmosphere produced from human activity (CO_2 , H_2O , NO_x) that absorb infrared radiation from the surface of the earth instead of letting it escape from the troposphere, similar to the effect produced in greenhouses.

Another worldwide pollution problem is acid rain. Acid rain is produced from sulfates. Primary sources are high sulfur coal burned to generate electricity and automobile emissions. These are emitted as gases but can become particulates downwind. The particulate by-products of these emissions are reintroduced to the environment when it rains, hence the term, "acid rain". Acid rain kills plant and animal life and corrodes buildings; moreover, it can be blown thousands of miles from its pollution source.

Vehicle emissions are a major contributor to urban air pollution. As a result, the transit industry is being faced with tougher emissions standards. These new emissions standards require either modifications to diesel buses or the introduction of another, alternative fuel source.

Vehicle emissions are responsible for 46% of the ground level ozone production in the Chicago region. Efforts to control bus emissions are targeted at reducing the production of ground level ozone and suspended particulates "smog". E.P.A. regulations are based on efforts to reduce smog and other poisonous effects from carbon monoxide and hydrocarbons. All the clean air proposals and E.P.A regulations are based on efforts to reduce these two types of emissions.

Legislative Efforts

Current Legislation: The increasing severity of pollution problems such as acid rain, the production of ground level ozone, and the "greenhouse effect" has led to several legislative initiatives. The discussion in this report, however, will be limited to measures to reduce hydrocarbons (HC), Carbon Monoxide (CO), particulates (PM) and Nitrogen Oxides (NO_x).

In March, 1985, the E.P.A. promulgated regulations to reduce emissions of nitrogen oxides (NO_x) and particulate matter in heavy duty engines. Buses were to meet the new standards by 1991, heavy duty trucks were to follow in 1994. Car and light duty truck standards remain unchanged.

These regulations prompted a strong protest from transit providers, mainly because the technology needed to meet these regulations would not be ready until 1994. The majority of heavy duty truck engines, which are the engines used in transit vehicles, will not be regulated as strictly as buses until 1994. Since buses only account for 1% of the heavy duty engine market, manufacturers have had little incentive for producing an engine which can meet the new standards or modifying existing engines for the 1991 time frame.

Administration's Clean Air Act: The Clean Air Act will expire in 1990. This past June the administration presented a comprehensive proposal to amend this act. The act is comprehensive and addresses acid rain, the "greenhouse effect" and ground level ozone. There are significant proposed changes for the transit industry. These changes are:

- It only affects transit operators in Standard Metropolitan Statistical Areas of over 1 million people.
- Requires a phasing in of alternative fueled transit vehicles beginning with model year 1991. All new transit vehicles must be alternatively fueled by model year 1994.
- Rolls back current E.P.A. regulations and puts diesel buses on the same schedule (compliance in 1994 instead of 1991) for particulate emissions reduction as heavy trucks.
- Provides the Secretary of Transportation with an option to delay the requirements for up to two years if the delay would substantially increase the benefits or decrease the cost.

The other important factor is that, beginning in 1994, a share of all new cars are also required to be alternatively fueled. Since the total transportation industry consumes a significant amount of petroleum (62% of all petroleum uses) compared to the transit industry (less than 0.5% of all petroleum uses), this will have a significant impact on the availability and price of the various alternative fuels.

Regional Legal Issue

In 1986 the State of Wisconsin filed a suit to force more stringent air pollution controls against Illinois. Wisconsin claimed that ozone created in Illinois drifted to Wisconsin causing excessive ozone levels. A court ordered study of regional (IL, WI, MI and IN) ozone production found that ozone emissions were so excessive that it ordered the EPA to take over individual state planning efforts and produce a Chicago area ozone control plan by March 1990.

The initial phases of the study have determined that the Chicago area must reduce its ozone precursor emissions by 72% in order to meet emission standards mandated in the Clean Air Act. However, a recent settlement of the lawsuit has delayed development of a plan until 1994 which will allow the E.P.A. sufficient time to analyze the source of area ozone production.

It is important to note that any local planning efforts will be superseded by changes in national clean air legislation, a priority of the Bush administration.

National Energy Policy

The current emphasis on alternative fuels is a component of national energy policy as well as environmental concerns. The combination of environmental concerns and national energy concerns can yield different results than if either was considered alone.

U.S. energy consumption is dominated by fossil fuels. Fossil fuels such as coal, petroleum and gas fuels account for over 50% of all U.S. energy consumption. Fossil fuels are non-renewable sources, and as such, have a limited supply. This diminishing supply of fossil fuels, when coupled with increasing use of fossil fuels, estimated at over 75% of all energy sources by 2010, has led to concerns regarding a stable long term fuel supply for the U.S.

There are two goals of the national energy policy which affect the consideration of alternative fuels for use in the transit industry: to diversify sources of energy to avoid dependence on a particular type of fuel or any particular geographic region of the world from becoming our sole suppliers of fuels. During the energy crisis of the mid seventies it became clear that dependence on foreign, potentially unfriendly sources was undesirable from a national security standpoint. The estimated dependence of the U.S. on foreign oil is projected to rise from a current level of 37% to anywhere from 68% to 83% of demand by the year 2000. The goal of reducing imported transportation fuel can be accomplished by two of the alternative fuels available to transit, compressed natural gas and ethanol. Although methanol is made from natural gas, it is primarily produced in the same areas of the world where our petroleum resources come from, therefore not shifting geographic dependence.

OVERVIEW

Fuel Characteristics

The properties of alternative fuels vary considerably from diesel. It is these differences that require redesigned engines, changes in fuel handling and storage and the development of new types of fueling stations.

Diesel is the common name for a #1 or #2 fuel oil. It is the primary fuel used in heavy duty engines. It is refined from crude oil, is flammable, and contains numerous toxic compounds.

Compressed natural gas (CNG) is natural gas stored in a compressed form in tanks at very high pressure, 3,000 psi (pounds per square inch) versus .22 psi gas used for home cooking purposes. Since this fuel is a gas, rather than liquid, the use of CNG in buses would substantially change the storage, fueling and maintenance requirements for the transit industry. Because of CNG's chemical properties, its harmful by-products or emissions are minimal. It is expected to be the cleanest burning viable transit fuel.

Methanol, commonly called "wood alcohol," is an alcohol made from natural gas, wood or coal. The methanol available for transportation is made from natural gas. It is highly toxic; drinking two ounces can be fatal. It is also highly corrosive which increases engine wear and maintenance costs. Methanol is less polluting than diesel with the exception of aldehyde emissions which are highly toxic. Aldehyde emissions are not currently regulated by the E.P.A. but it is likely that they will be in the near future. Aldehyde toxicity could be very expensive to control in a closed area such as bus garages. Methanol is also currently the preferred alternative fuel of the E.P.A.

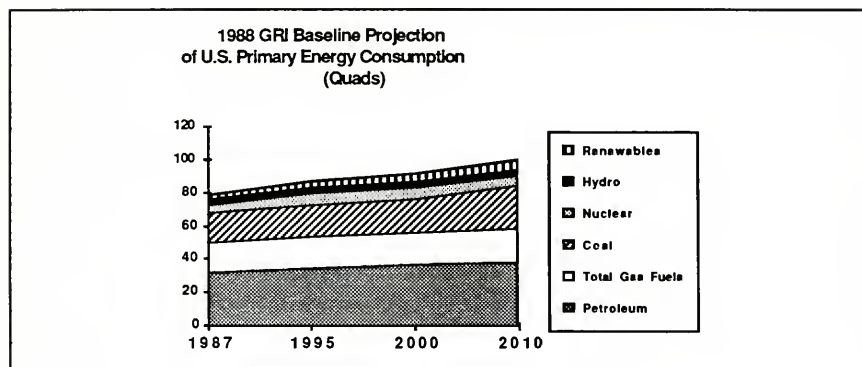
Ethanol is manufactured from corn, sugar and other starches and is a renewable fuel. It is a clean burning alcohol that can be blended with gasoline to form gasohol. It is too expensive to use in a pure form but, blended with gasoline, is the primary non-fossil alternative motor fuel in the U.S. today. Similar to methanol it is a slower burning and thus a cleaner fuel.

Fuel Availability

There are six types of energy sources: Petroleum, Gas Fuels, Coal, Nuclear, Hydroelectric and Renewables. Consumption of a particular type of fuel varies by country. Chart 1 is a projection of U.S. energy consumption. Since alternatives to petroleum such as nuclear, hydroelectric and coal are currently not feasible for transit uses they are not addressed in this study. Three alternative fuels are available to power buses: two gas fossil fuels -- methanol, compressed natural gas (CNG), and one renewable source -- ethanol. Ethanol is produced from feedstocks such as corn, sugar and other starches.

However ethanol is four times as expensive as diesel and is currently produced in such limited quantities as to rule it out as a realistic option for transit use in the next ten years. Hence, the alternatives currently available to transit involve trading dependence on one fossil fuel, petroleum, for another - methanol or CNG.

Chart 1



Switching to an alternative fuel source also changes the transit industry's dependence from the oil industry to a regulated utility in the case of compressed natural gas, the chemical industry for methanol and the agricultural processing industry for ethanol. In all three cases price, availability and supply would be substantially affected. The outlook also differs depending on the market size, i.e., only transit vehicles or the entire transportation industry. The individual fuel summaries address these issues in greater detail.

While the U.S. transit industry is petroleum dependent, it accounts for less than 0.5% of all U.S. petroleum consumption. Thus, if the entire transit industry converted to an alternative fuel it would have a negligible effect on reducing U.S. consumption of petroleum products. Total transportation consumption represents well over half of total petroleum consumption.

As long as alternative fuel use is limited to the transit industry the long term availability, supply and price of the various options will be unaffected by the addition of transit use.

However, if the Clean Air Act is amended to include cars, as is proposed, there would be a major impact on fuel availability, supply and price since vehicles account for 62% of all petroleum uses. This would affect the economics of alternative fuel usage for the transit industry.

Current Research

The Urban Mass Transportation Administration (UMTA), utility companies and engine manufacturers have been working to evaluate alternatively fueled buses. Research results pertaining to a specific fuel are discussed in greater detail in the individual fuel sections.

Studies -- UMTA has contracted for two major studies regarding alternative fuels. One, a review of fuel availability, supply and price for methanol and CNG was completed by the Battelle Memorial Institute. The second, a comprehensive analysis of the technology available to meet emissions standards, was completed by Argonne National Laboratories. The E.P.A. has also completed its own review of methanol. The E.P.A. plans to review the other alternative fuels within the next year.

Detroit Diesel Allison Corporation (DDA) is developing a methanol engine which may be ready by 1991. The Cummins Company is developing a CNG powered engine. The availability of this engine has not yet been announced. Most major engine manufacturers are developing particulate traps for use on diesel fueled engines. However, it is unlikely that they will be ready before 1994 when heavy duty truck engines will be subject to tighter emission standards (See Appendix A).

Demonstrations -- UMTA, in conjunction with the private sector, has sponsored several small demonstrations of alternatively fueled vehicles. At this time, far more operating data has been collected on methanol than on CNG. Experiments of methanol powered buses have been conducted in cities such as Riverside, California, Seattle and New York City. Enough data has been collected to highlight emissions problems and evaluate the impact on operating costs.

Tests of CNG began much later due to the lack of a dedicated CNG engine. At this time the Command Bus Line, a New York City private operator has the only CNG buses (sponsored by Brooklyn Union Gas) in operation long enough to generate any operating data. Consequently, few conclusions can be drawn regarding actual operating costs, nor can technical problems be identified.

It should be noted, however, that most natural gas company fleets are powered by CNG. While most of these vehicles are vans, some insights as to fueling stations and fuel handling and storage requirements can be gained.

Current Technology

It is important to make a distinction between technologies which involve retrofitting diesel engines and dedicated fuel engines, i.e., engines designed for a specific fuel.

A recent study conducted by Kenneth Small of the University of California at Irvine evaluated the cost-effectiveness of three strategies; low aromatic fuels, particulate traps and methanol fuel, for reducing particulate and sulfur-oxide from diesel transit buses. Low aromatic fuels such as low sulfur were the most cost-effective options followed by particulate traps and methanol fuel. Low sulfur fuel was also cited as potentially reducing engine wear and cold start problems.¹

Particulate traps, injection systems and dual fuel systems all involve retrofits of diesel engines. Injection systems introduce a small amount of a cleaner burning alternative fuel like ethanol to the fuel stream prior to entering the combustion chamber. Dual fueled systems allow switching between diesel and another fuel such as CNG. Particulate traps reduce diesel engine emissions by capturing particulates. None of these technologies has demonstrated that it can meet all the 1991 emission requirements, including reliability and durability.

These are attractive options because they involve retrofits of existing diesel engines which is much cheaper than purchasing an engine that can only burn one fuel, a dedicated fuel engine. These options also do not require any significant start-up costs such as new maintenance procedures and changes in fueling facilities.

Dedicated fuel engines are being developed for methanol and CNG. Since they are designed to the characteristics of a specific fuel they handle the fuel more efficiently than a diesel retrofit. Since dedicated fuel engines are still being developed, many test results for a specific fuel, such as methanol, use retrofitted diesel engines. As tests of alternatively fueled buses are based more on dedicated engines, fuel efficiency, engine reliability and emissions can be expected to improve.

Also, some dedicated fuel engines, such as CNG powered, are four stroke rather than the traditional two stroke diesel bus engine. This change in engine technology could have two impacts. Two stroke engines usually provide greater "torque" or propulsion per unit of engine weight and volume than four stroke. While this is preferable for buses, it is not necessary. It is also probable that operating costs for four stroke engines would be higher.

Ethanol tests have been limited to injection systems. Experiments, conducted in Des Moines, Iowa by Midwest Power Concepts have shown that lower operating costs than 100% diesel powered buses may be achieved.

Emissions Testing -- Finally, New York City Department of Environmental Protection is using a different method than the E.P.A. in monitoring emissions. New York evaluates emissions by the amount of grams per mile and is measured at an average speed of approximately 8.8 mph, the average speed of an urban bus compared to the E.P.A.'s method where emissions are measured in grams per brake horsepower per hour and the testing cycle reflects a combination of urban and highway speeds, approximately 22 mph. The E.P.A. also uses the same testing cycle for all heavy duty truck engines.

The New York test results have been cited as a more realistic estimate of the amount of ground level bus emissions in a given area of the city. If the E.P.A. switches to the New York method of measuring emissions for buses, then the use of methanol or CNG on buses operating in dense urban environments may not meet current or proposed emission standards. The industry could be facing further restrictions in the near future.

Cost Impacts

The cost impact of converting Pace and CTA buses to an alternative fuel is limited to an analysis of CNG, methanol and particulate traps. Since ethanol is four times as expensive as diesel the high operating cost ruled it out as an option. Estimates of the specific operating and capital costs for CNG and methanol are contained in the report appendix and are outlined under the fuel summary. The increase of both operating and capital costs can be attributed to the need to compress natural gas to create CNG and the corrosiveness and toxicity of methanol.

The major capital costs for converting to an alternative fuel source are more expensive buses, \$5,000 to \$20,000 per bus, new fueling stations and storage tanks and improvements of HVAC (heating, ventilation and air conditioning) systems in bus garages.

Increases in operating costs are mainly due to the increased fuel costs, reductions in engine efficiency and potentially less reliability and durability of operation. More detailed analysis of costs is presented in each fuel section.

FUEL SUMMARIES

Diesel

Fuel Characteristics: Diesel is the common name for a #1 or #2 fuel oil. It is the primary fuel used in heavy duty engines. It is refined from crude oil, is flammable, and contains numerous toxic compounds.

Availability and Price: If U.S. dependence on petroleum continues, then the country can anticipate an increasingly expensive and unstable fuel supply through the end of the century.

The estimated dependence of the U.S. on foreign oil is projected to rise from a current level of 37% to anywhere from 68% to 83% of demand by the year 2000.² (Most likely this increased import requirement would come from the Middle East because of the huge, low-cost surplus production capacity in that region)³ Meanwhile, U.S. petroleum production is projected to decline from nearly 10 million barrels per day in 1987 to 6.6 million in 2010. Oil imports, therefore, would reach 12.4 million barrels per day by 2010.⁴

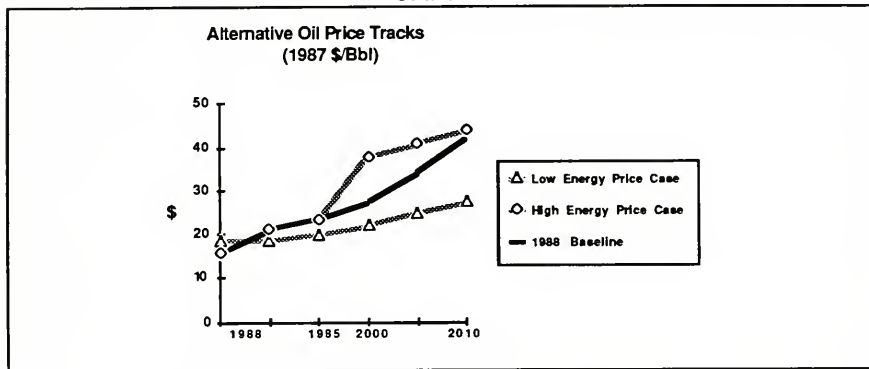
As Table 1 shows that while the U.S. transit industry is petroleum dependent, it accounts for less than 0.5% of all U.S. petroleum consumption. Thus, if the entire transit industry converted to an alternative fuel it would have a negligible effect on reducing U.S. consumption of petroleum products. As long as the transportation industry is dependent on petroleum products, little change in U.S. demand for petroleum is expected.⁵

Table I

Petroleum Consumption (millions)		
	<u>Gallons</u>	<u>%</u>
Total U.S. Consumption	169,344	100%
Transportation Industry	91,446	54%**
Transit Consumption*	515	.3%
* 1986 Section 15 Annual Report*		
** Excluding aviation fuel. Including aviation fuel the transportation industry's share increases to 62%.		

The following graph highlights three future U.S. oil price scenarios developed by the Gas Research Institute, a baseline, low and high oil prices. These estimates provide a range of price impact of a fluctuating world oil supply.

Chart 2⁶



The Gas Research Institute's 1988 baseline projection of oil price trends assumes stability at the current price level until after 1990, price escalation beginning in the 1990's which increases after 2000 when Middle East sources dominate supply. The "low" estimate assumes that today's relatively low prices will persist if OPEC cannot control oil production. The "high" energy price case assumes high oil prices due to a worldwide disruption of oil flow. Other sources project the price of petroleum to be even higher, closer to \$67/barrel by 2010 as compared with current levels of \$18/barrel.⁷

Emissions - Current Technology: The current E.P.A. emissions regulations allow diesel buses outfitted with particulate traps to be an acceptable technology for meeting the current 1991 emissions requirements. These traps reduce diesel emissions by capturing particulates, a key component of ground level ozone. The development of particulate traps is still underway, since the bulk of the heavy duty diesel market is not subject to the regulation that affect diesel buses, until 1994.

It is difficult to obtain emissions data from manufacturers regarding particulate traps. (It is considered a trade secret since they are under development). According to one manufacturer, Detroit Diesel, it is improbable that they will be commercially available to meet the 1991 emission standards. The two main hurdles they must overcome are durability - the E.P.A. requires durability of five years on any new technology, and reliability. It is more likely that traps will be ready in 1994.

Of the several types of traps under development, the ceramic monolith with a catalytic afterburner is considered cheapest and most effective for reducing pollution.⁸

If the President's Clean Air proposal is adopted in its current form, particulate traps will not be a viable solution to address the Clean Air Act. Even though the new emissions regulations are rolled back to 1994, the President's proposal calls for alternatively fueled buses beginning in 1991. The current administration proposal also requires existing diesel buses to use low sulfur diesel fuel by 1993. Low sulfur diesel fuel is a cleaner burning fuel

than the diesel currently in use. The cost is \$.05 a gallon higher than diesel fuel currently being used.

Cost Impacts: The cost impacts for modifying a diesel engine to meet the tougher emissions standards is minimal in comparison to converting to an alternative fuel such as CNG or methanol. The changes to diesel engines that are necessary to meet current emission standards are limited to the installation of particulate traps and the use of low sulfur fuel.

Particulate traps will cost approximately \$5,000 per bus. Converting bus fleets would cost the CTA \$11.2 million and Pace \$2.5 million (constant dollars), for a total regional cost of \$13.7 million. No other modifications to either Service Board's garages would be required. However, there is a fuel economy penalty which may be as high as four percent.

Low sulfur diesel fuel costs \$.05 more per gallon than the current grade of diesel #2. Switching to low sulfur fuel would result in an annual operating cost increase of \$1.2 million for the CTA and \$0.2 million for Pace, for a total regional operating cost of \$1.4 million. The impact on the Service Board's overall operating budgets would be minimal, 0.2% increase for CTA and 0.3% increase for Pace. Since the fuel and the technology remain relatively constant, it is likely that no additional operating cost would be incurred. (See Appendix D)

Policy Issues: As long as current E.P.A. emissions standards remain in effect, new diesel engines fitted with particulate traps are the most cost effective way of meeting the requirements. However, a mandatory switch to alternative fuels would exclude this option and substantially increase the cost to the CTA and Pace.

Since the average life of a bus is 12-16 years, mass transit systems can expect to be at least partially dependent on diesel fuels until the year 2010. Thus even if mass transit were to convert to an alternative fuel source, most systems would remain dependent on petroleum for the next several years.

Natural Gas

Fuel Characteristics: Compressed natural gas is natural gas stored at a very high pressure, 3,000 psi (pounds per square inch) versus .22 psi gas used for home cooking purposes. This high pressure, in addition to the amount to energy in a tank makes it explosive. However, the structural integrity of CNG cylinders is sufficient to withstand crashes and fires. High pressurized gas (3,000 psi) also disperses more easily than gas which is pressurized at less than 100 psi, thereby reducing the potential for an explosion.

Since this fuel is a gas, rather than a liquid, conversion to CNG would substantially change the storage, fueling and maintenance requirements for the transit industry. Fueling requires special compressor systems rather than the traditional pump for liquids such as methanol, ethanol or diesel. CNG is less dense than liquid fuels as a result, buses must be fitted with larger gas tanks. Therefore, increasing the weight of the bus and leading to lower fuel efficiency and a greater load of the bus frame.

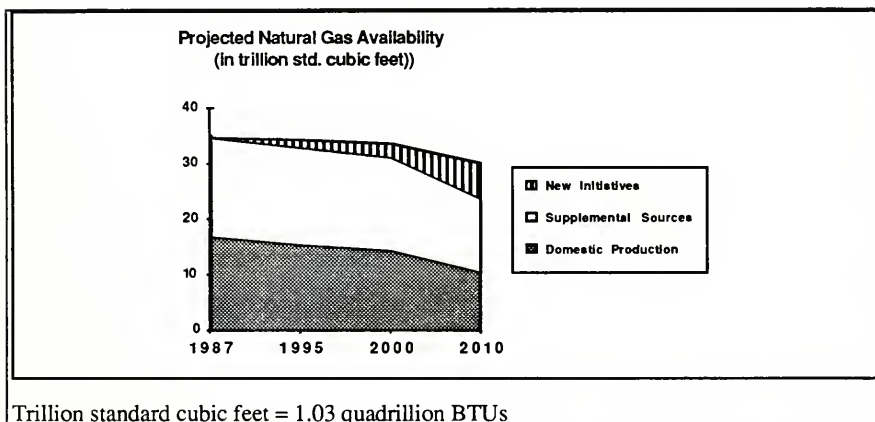
Because of CNG's chemical properties, it's harmful by-products or emissions are minimal, even though CO and NO_x emissions may be a problem. It is expected to be the cleanest burning viable transit fuel.

Availability and Price: The cheapest way to ship natural gas over oceans is in liquified form (LNG). However, LNG tankers can explode extremely violently. Natural Gas is highly volatile and cannot be easily transported by tanker.⁹ Therefore any discussion of reserves is pragmatically limited to North America, where fuel can be transported by pipeline. Thus while proven world reserves are sufficient until the middle of the next century, proven reserves for North America are 15 years, based on current consumption rates.¹⁰

There is debate as to the future supply of natural gas. Industry experts and some academics argue that proven reserves are not an accurate measure of the future supply of natural gas. These experts rely on a 70 year estimate based on total estimated reserves-- i.e. proven, inferred, undiscovered and unconventional sources. Unconventional sources cited are gasification of coal, shale and biomass.¹¹

As Chart 3 indicates, the Gas Research Institute's 1988 baseline projections estimate a decline in natural gas from conventional sources and a subsequent increase in the amount of fuel from unconventional sources by 2010.

Chart 3¹²



Current U.S. natural gas consumption is one-half that of petroleum. Demand has dropped from a high of 22 tscf in 1971-73 to 16.9 tscf in 1988. (tscf = trillion standard cubic feet) This was due to conservation, a partial deregulation of natural gas prices and the drop in world oil prices.¹³ Forecasts show future gas demand of 17-20 tscf in 2000 depending on the forecaster and the scenario. These estimates do not include any increase due to higher consumption by the transportation industry or generation of electricity. The range is depicted in Table II.

Table II

Demand for Natural Gas (Projection for Year 2000)		
	<u>Standard Cubic Ft. (Trillion)</u>	<u>% of all Energy Consumption</u>
WEFA	17.0	20.6%
EIA/DOE	20.4	23.2%
GRI	18.3	21.3%
A.G.A.-1	19.2	23.9%
WEFA = Wharton Econometric Forecasting Asssts		
EIA = Department of Energy, Energy Information Administration		
GRI = Gas Research Institute		
A.G.A. = American Gas Association; Business-As - Usual Case		

If all transit vehicles were to convert to CNG, natural gas use would increase by .42% or an additional 71.5 bscf of gas. Shifting twenty percent of all U.S. transportation needs (this would include cars) to natural gas would require 3.3 tscf, for a total projected usage of 20.2 tscf. Since this total is less than the 22 tscf of demand experienced in 1972, much of the needed infrastructure is in place in most regions of the country. If demand does not exceed the 1971-73 levels, prices would be expected to increase modestly.¹⁴

The supply of natural gas appears to be sensitive to prices rather than worldwide reserves.¹⁵ Natural gas has a history of shortages and unstable prices, although to a lesser degree than oil. With deregulation, this pattern could change.

Since natural gas is linked to oil reserves its availability is subject to similar dynamics as oil. Since oil prices are anticipated to rise, an increase in natural gas prices is also predicted. The wide range of price scenarios for 2010, \$4.50-9.68/mscf (mscf= million standard cubic feet), reflects a similar range of world oil prices, \$27-62/ barrel.¹⁶

Two factors could potentially stabilize gas prices. The first, the free trade agreement with Canada, "... limits the ability of the two governments to control the flow of energy materials such as gas and oil by taxation." This has the potential of stabilizing the supply and price of natural gas. Imports are expected to increase; prices are expected to be lower in California and the upper Midwest when there is an extensive network of pipelines. Second, the completion of price deregulation is also likely in the near future.

Emissions - Current Technology: Most manufacturers indicated that a CNG powered two stroke engine will not be available to meet 1991 standards, however a 4 stroke engine is currently being tested. Cummins has announced that a 4 stroke CNG engine would be available in 1991 (See Appendix A). Two stroke engines are preferable to four stroke engines because they provide the "torque", or propulsion that buses need.

Other technological hurdles that CNG buses face are the increased storage space and weight of CNG fuel tanks. Increasing the bus weight potentially reduces the number of passengers that a bus can carry and decreases the fuel mileage. In addition, the higher weight could negatively impact the overall life cycle of the bus. Also limited fuel storage (60-70 gallons of CNG vs. 90-120 gallons of diesel) decreases the bus's range. Refueling could be required mid-route or a higher vehicle spare ratio could be required to service routes.

CNG fueling can be either a slow or fast fill method. Fast fill method takes 3 to 5 minutes but requires CNG to be stored at 3000 psi and is more capital intensive than slow fill. Slow fill pumps regulate natural gas through a high pressure system but take 8 hours to fill a vehicle. Since the maximum available fueling time for CTA buses is five hours this significantly increases the capital costs for CNG. However the slow fill method could be appropriate for Pace buses since they are only on the road an average of eight hours.

Like other developing technologies, CNG powered engines would benefit from a delay in regulations from 1991 to 1994.

Test results of ground level emissions of alternative fueled buses may not reach E.P.A.'s emissions standards. Both Argonne Laboratory and the New York CTA have concluded that the reduced speed of urban buses requires a different measure of emissions than is currently used by the E.P.A.

Cost Impacts: CNG operating and capital cost estimates vary widely. This variance is due to a number of factors: fuel costs, spot market vs. regulated prices (see discussion below) and fuel efficiency and technological innovations.

The Gas Research Institute estimates that CNG vehicles require 1.725 the amount of diesel fuel BTU's to achieve equivalent mileage. Recent tests of CNG GM modified engines by Brooklyn Union Gas in New York City reveal that energy efficiency may actually be equal the efficiency of diesel engines. If the Brooklyn Union Gas experience is upheld then, the equivalency factor would drop to 1.38 (See Appendix B).

The total estimated additional capital cost for the CTA and Pace is \$83.2 million for garage conversions and \$41.1 million for new buses for a total of \$124.4 million (constant dollars) over a 12 year period. It would cost the CTA \$56.1 million to convert all garages and an additional \$33.7 million to replace its fleet with CNG rather than diesel buses. Pace could spend from \$11.9 million to \$27.7 million to convert its garages as well as an additional \$7.4 million to replace its fleet. Potential costs relating to the heavier fuel tanks and reduced storage capacity on board the buses have not been addressed. (See Appendix C.)

The main factors affecting capital conversion costs are high compressor stations, approximately \$1,000,000 each to purchase and install, as well as fire protection and fueling stations.

The high compressor station is for "fast fill" rather than a "slow fill" method. The slow fill method for a Pace garage with a 25 to 35 bus capacity would only cost \$320,000. Pace garage conversion estimates include both slow fill and fast fill methods. Due to the limited fueling time available, CTA garage conversion estimates are limited to the fast fill method. Since an entire facility conversion has not yet occurred these estimates are subject to change.

Most of the demonstrations of CNG buses are in the early stages. There is insufficient data to develop a good estimate of other operating costs such as ongoing maintenance. Our analysis assumes a higher level of maintenance costs than diesel, but it is based on preliminary results. Early expectations that CNG would extend engine life because it is less corrosive than liquid fuels have not materialized.

CNG is competitively priced with diesel. The price of one gallon of diesel is around \$.48, the cost of the same energy equivalent amount of CNG ranges from \$.36 to \$.69 (See Appendix B). Depending on the method of purchase, spot market vs. regular contract as well as the energy equivalence factor used. Depending on the scenario used, overall fuel costs for the CTA and Pace could vary from \$10.2 million to \$19.3 million per year. Total annual fuel costs in 1988 for CTA and Pace were \$13.6 million (See Appendix D).

Operating costs are affected by fuel costs and increased maintenance costs. Fuel prices vary considerably .

Clearly a better refinement of CNG's operating and capital costs is needed. One point can be made, however, the substantial range of CNG fuel prices is an indication of a continuing pattern of unstable prices, and raises concerns about dependence on CNG.

Policy Issues: Since it appears that domestic natural gas reserves will be available for the next 35-50 years, natural gas could meet transportation's demand for a long term fuel supply. This would reduce dependence on foreign sources. The fuel's relative abundance, in addition to a well developed distribution network, makes it an attractive alternative to diesel. However, there is no guarantee of low or stable prices.

Methanol

Fuel Characteristics: Methanol is an alcohol made from natural gas, wood or coal. It is more commonly called "wood alcohol." The methanol available for transportation is made from natural gas (see discussion below). It is highly toxic; drinking as little as two ounces can be fatal. It is also highly corrosive which increases engine wear and maintenance costs.

Methanol has 44% of the energy equivalent of a gallon of diesel, requiring significantly more fuel. Methanol is slower burning than diesel. The level of emissions is dependent on the speed of the vehicle. Higher speeds emit higher levels of pollutants. Thus it creates less hydrocarbons, particulates and nitrogen oxides and creates less ozone problems. However it creates ten times the amount of formaldehyde emissions than diesel fuel.

Availability and Price: Methanol can currently be manufactured from two sources: natural gas and coal. At this time however, coal is not a competitively priced source compared to natural gas due to high production costs that are likely to remain constant over the next few years. Beyond 2000 new technology, using natural gas, may reduce production costs 2-3¢/gallon. Gasification of coal produces sulfur, hydrocarbons and ash that are very expensive to clean.

Unlike natural gas, methanol can be cheaply and easily transported by tanker over great distances. Hence it has a worldwide rather than a domestic market. Improvements to the methanol distribution network would be required for widespread use of methanol in the U.S. ¹⁷ "Most imported Methanol comes from plants in gas surplus countries (mainly

Saudi Arabian) that convert natural gas otherwise flared (burned at the well head for safety reasons) into the easily transportable liquid fuel, methanol. The price of this imported methanol is usually considerably less than domestically produced methanol."¹⁸ Other major suppliers include Chile and Trinidad and Tobago. If the price of imported methanol remains substantially below domestically produced methanol, a conversion to methanol would not result in decreased reliance on foreign energy sources.

The short term availability of this fuel is dependent upon the production capacity. The production of methanol is very capital intensive and plants are economical to build only at very large scales. In the 70's and early 80's a large number of plants were built in anticipation of a widening market to replace expensive petroleum products. This market never materialized because diesel oil and natural gas prices began a sharp decline in the early 80's. This resulted in a large industry overcapacity worldwide. A portion of this over-capacity has been consumed by MBTE (MBTE is produced using methanol as a feedstock) and it is used as an octaine enhancer in gasoline.

The Saudi Arabians, a major producer of methanol, estimate that the supply of methanol will remain tight until 1995.¹⁹ Although several closed plants will be reopened there are not a sufficient number of new producers or expansion of existing plants to provide any additional excess capacity in the near future

"Replacing all the transit diesel fuel with methanol, at 2.8 gal. to 1 gal. of diesel, and gasoline, at 2 for 1, would require an additional 1.4 billion gallons, almost equal to current U.S. usage."²⁰ It remains to be established whether a sufficient number of plants that were mothballed in the early 1980's could be reopened, thus eliminating this problem. If not, new plant construction would be required and prices would be likely to increase, at least in the short term.

The worldwide supply of methanol, or production capacity, only becomes a problem if the entire transportation industry is involved. If all of the U.S. transportation industry were to instantly use methanol then the price would be almost sure to increase. If "... the 20 percent of the 130 billion gallons per year of hydrocarbon transportation fuel in the U.S. was replaced by methanol, the new demand would be about 52 billion gallons, assuming two gallons of methanol to replace each gallon of hydrocarbon fuel. Since world methanol capacity is only about 6 billion gallons per year, massive new plant construction would be required."²¹

Since methanol is derived from excess natural gas that is not otherwise easily transported, the supply has few restrictions on price. Thus, methanol price shifts have been due to methanol production capacity availability, not variations in natural gas supply or price. Fluctuations in the price in the next decade will probably also occur as the result of the degree of capacity utilization and the price accepted by exporters in gas surplus countries.²² The California Energy Commission estimates that when production is at 73-82% of plant capacity then demand and price is stable.²³

If methanol imports continue to be cheaper than domestic production then the U.S. would be increasing its dependence on foreign fuel sources such as Saudi Arabia and the Soviet Union. While this may be economically feasible it may not be practical if the U.S. policy is to reduce dependence on foreign fuel sources.

Emissions - Current Technology: Detroit Diesel anticipates having its 6V92A methanol engine ready to meet the 1991 standards. However this engine was tested with 100% Methanol. The engine does not meet the 1991 hydrocarbons standards with Methanol 85, a

mixture of 85% methanol and 15% gasoline. Methanol 85 is considered a fuel source more likely to gain widespread use because it eliminates the cold start problems associated with 100% Methanol.

Methanol engines also produce aldehyde emissions which are very toxic. This toxicity could be very expensive to control in closed areas such as bus garages. Aldehydes are not currently regulated by the E.P.A. but it is likely that they will be in the near future (See Appendix A).

Cost Impacts: The total additional capital cost for the CTA and Pace is estimated to be \$100.0 million for garage conversions and \$54.9 million for new buses for a total cost of \$154.9 million (constant dollars). It would cost the CTA \$75.6 million to convert all garages and an additional \$44.9 million to replace its fleet with methanol rather than diesel buses. Pace could spend up to \$24.4 million to convert its garages as well as an additional \$9.9 million to replace its fleet (See Appendix E).

The main factors which contribute to the capital conversion costs are the ventilation, electrical system modifications and fire protection system modifications required due to the high toxicity of the fuel. The high toxicity of aldehydes may require further, more expensive forms of ventilation. These estimates also do not reflect the City of Chicago fire code regulations. When the New York City TA met with city fire department officials the cost estimate for a garage conversion to accommodate it's buses estimate grew to \$22.2 million, compared to earlier expectations of \$5 to \$7 million.

A major drawback with methanol is its substantial impact on operating costs. Methanol fuel energy equivalents are 2.28 times greater than diesel. Total methanol fuel costs for the CTA are \$26.23 million compared to \$11.42 million for diesel (See Appendix D). Pace fuel costs are \$4.9 million for methanol compared to \$2.156 million for diesel. Actual operating experience has been more pessimistic. Seattle Metro reports an energy equivalency at 2.8 times diesel.

Maintenance cost estimates are based on Seattle Metro's experience testing 10 methanol buses against 125 diesel buses. Methanol bus costs were 30% higher for parts and 14% higher for labor due a greater frequency of breakdowns and caution exercised due to the volatility of the fuel.

Although methanol is the E.P.A.'s preferred fuel, it has much higher operating and capital costs than diesel. The capital costs for methanol are higher than CNG, both requiring about \$155 million in additional capital costs compared to \$124 million for a CNG conversion.

Policy Issues: Methanol currently is the E.P.A.'s favored alternative fuel. E.P.A. officials cite the fact that it is not as combustible as natural gas and that it has a large number of sources.

If particulate traps remain an option or if the oil and car industries develop a petroleum fuel alternative (low sulfur diesel), the high operating costs of methanol would most likely make it, at best, only a short term solution unworthy of a major capital investment.

If the U.S. energy policy is to reduce dependence on foreign fuel sources than the high percentage of foreign imports makes methanol less attractive as an alternative fuel source.

Ethanol

Fuel Characteristics: Ethanol is currently the only renewable source of fuel that has potential for transit use. Ethanol is manufactured from corn, sugar and other starches. It is a clean burning alcohol that can be blended with gasoline to form gasohol. It is the main alternative motor fuel in the U.S. today. Similar to methanol it is a slower burning and thus cleaner fuel. The energy equivalence of ethanol is 60% that of diesel.

The primary use of ethanol is blending it with gasoline to form gasohol. Currently ethanol replaces 1% of gasoline consumption.

Availability and Price: Ethanol is currently not an economically competitive fuel for transit. It is twice as expensive to produce as other alternative fuels and is produced in small quantities. Unless federal subsidies continue, large scale production in the near term (ten years) is unlikely.

The current U.S. production capacity of ethanol is one billion gallons per year. The U.S. has approximately 150 plants. Most of them are located in the Midwest. However the majority of ethanol production is from a few large facilities.²⁴ "Potential resources for ethanol production appear to be sufficient so that supply will not be limiting factor for use in the transportation sector."²⁵ The primary feedstock source for ethanol produced in the U.S. is corn. The U.S. excess grain capacity is great enough to be able to absorb an expansion in ethanol production. The future feedstock supply could be expanded if cellulosic feedstock (e.g. wood, plant stalks) conversion is developed.²⁶

"New ethanol production facilities will depend on the gasoline blending market expanding to its maximum potential, feedstock supplies and prices remaining stable, and the continuation of the federal tax subsidy."²⁷ Since production costs are higher than competitive fuels, an expansion of ethanol capacity in the near future is unlikely.

If all transit fleets were to convert to ethanol, an estimated additional 880 million gallons would be required. This conversion assumes a fuel equivalency of 1.7 gal of ethanol to 1 gal of diesel and gasoline. This would require U.S. production capacity to increase 88% (See Appendix F).

Ethanol now costs \$1.25 a gallon (without the federal subsidy). Ethanol is subsidized by a fuel tax credit of \$.60 a gallon. Unless it is renewed by Congress, this subsidy will end in 1993. The California Energy Commission estimates that technological improvements in process control and waste heat use could reduce production costs by 9 cents per gallon by 2000.²⁸ This would lower the price of ethanol to \$1.16 a gallon. This is still beyond the range of being competitive with other fuels.

The effect of large scale production on the price of ethanol is unknown. It is likely that large scale production would lower the cost. Whether this could make it competitive with other fuels is unknown. Substantial financial incentives from the government are needed to continue research and development in the field if ethanol is to move beyond its current development of being used as a gasoline blend. In the late 70's and early 80's, Brazil achieved a large scale conversion to ethanol. It continues to require substantial tax incentives as well as other public sector involvement. Although the public sector continues to play a major role it has not been a consistent or well organized public policy. This experience has led one expert to conclude, "Without the stabilizing influence of coherent public sector, uncertainty in the marketplace will be so great as to discourage investments in non-petroleum fuels until well after the market sends price signals that a particular production investment is economically attractive."²⁹

Emissions - Current Technology: At this time a separate ethanol engine has not been developed. However, Detroit Diesel has tested its two stroke methanol engines with ethanol fuel. The emissions results are lower than the methanol.³⁰

Cost Impacts : Ethanol fuel is 4.25 times costlier than diesel and twice as expensive as natural gas or methanol. Thus, the increased operating cost is so prohibitive that without substantial technological improvements, ethanol is currently not a viable option for the region's near term fuel needs (See Appendix D).

Policy Issues: Ethanol's popularity as an alternative fuel is based on two factors. First it is a renewable source that can be domestically produced. It is also the result of the powerful farm lobby and several years of tax incentives.

Price subsidies for ethanol are the result of U.S. support of sagging corn prices. The extent to which the U.S. continues to support corn prices by stimulating ethanol production is a factor in ethanol price, availability and widespread production. The E.P.A. considers it poor public policy to rely on ethanol which is made from a food source. Further development requires substantial continued government support. It is not clear whether the federal government is likely to continue its tax incentives beyond 1993.

SUMMARY

The current technology, fluctuating regulations, widely variant fuel availability estimates and high estimated capital and operating cost do not make the selection of a specific fuel for the region advisable at this time . Caution should be exercised for the following reasons:

- Current E.P.A. regulations can be anticipated to change substantially within the next year. The E.P.A. will promulgate a Federal Implementation Plan (FIP) for ozone in the Chicago area by March 18, 1990. The Administration's Clean Air proposals could significantly alter the current regulations by phasing diesel buses out of existence. If this scenario occurred, then switching to another fuel would be mandatory. The President's proposals also give the Secretary of Transportation a two year delay if technology is not readily available.

If, however, the oil and auto industries succeed in developing an alternative such as a different blend of fuel, the need for a major capital investment could disappear.

- Cost estimates for the conversion to CNG and methanol require further refinement if a reliable comparison is to be made. Current estimates are based on an order of magnitude rather than an actual cost. A conversion to an alternative such as CNG or methanol would have a significant impact on the RTA's discretionary funds which would in turn impact available funds for capital . Fuel costs alone could double.
- If only the transit industry were to convert to methanol or CNG the supply would be stable because transit consumption is a small percentage of overall consumption. However, if the entire transportation industry converted to one of these fuels, there may be an unstable supply due to current capacity constraints.
- Test results of ground level emissions of alternative fueled buses may not reach E.P.A.'s emissions standards. Both Argonne National Laboratory and the New York City TA have concluded that the reduced speed of urban buses requires a different measure of emissions.

RECOMMENDATION

The RTA recommendations are:

- I. Delay a decision on the consideration of fuel conversion until:
 1. Solutions to the safety aspects of these fuels are further developed;
 2. Suppliers of alternative fuels develop plans that will provide sufficient fuel supplies at reasonable costs;
 3. Engine manufacturers develop a better, more efficient engine to handle alternative fuels; and
 4. A New Clean Air Act is adopted by Congress.
- II. Continue to cooperate and work together with fuel suppliers, engine manufacturers and other government agencies to refine the cost and improve technology. Specific steps the RTA should take are:
 1. Share the results of our research with the Service Boards;
 2. Continue to communicate with other transit agencies around the country who are doing actual demonstrations, and refine the costs. Monitor and evaluate new and emerging technologies.
 3. Work with CNG suppliers in the region to get better estimates of the cost to convert to natural gas.
 4. Work with the Service Boards to determine specific concerns which could be addressed by a demonstration of alternative fuels and, if warranted, develop a demonstration for either an alternative fuel or new generation of diesel engine and/or diesel fuel.
 5. Reserve sufficient funds to implement a demonstration in late 1990 if warranted.
- III. Focus lobbying efforts to make the use of alternative fuels optional **not** mandatory.

¹Kenneth A. Small, "Reducing Transit-Bus Emissions: Comparative Cost and Benefits of Methanol, Particulate Traps and Fuel Modifications", Institute of Transportation Studies, University of California, Irvine, March, 1988, pp. 9-15.

² "The Forecasts: How They Vary on Imports and Production", National Petroleum News, March 1987, Vol. 79, No. 3, p.42.

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- ⁴ "Policy Implications of the 1988 GRI Baseline Projection of U.S. Energy Supply and Demand to 2010", from GRI Insights, Gas Research Institute, Chicago, IL, December, 1988, p.2.
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- ⁷ W.J. Sheppard, "Natural Gas Price and Reserve Outlook," Battelle Memorial Institute, Columbus, OH, May 3, 1989, p.8.
- ⁸ Kenneth A. Small, "Reducing Transit-Bus Emissions: Comparative Cost and Benefits of Methanol, Particulate Traps and Fuel Modifications", Institute of Transportation Studies, University of California, Irvine, March, 1988, p. 12.
- ⁹ Although liquid natural gas (LNG) can be transported by tanker it is not economically feasible to do so at this time. This fuel is so highly volatile that it requires extreme safety precautions and consequently, higher fuel costs. W.J. Sheppard, "Natural Gas and Price Reserve Outlook," Battelle Memorial Institute, Columbus, OH, May 3, 1989, p. 14.
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- ¹⁴ W.J. Sheppard, "Natural Gas Price and Reserves Outlook", Battelle Memorial Institute, Columbus, OH, May 3, 1989, p.16.
- ¹⁵ "The mainstay of future supply... is production from domestic gas resources using technologies considered "conventional" in the field. This resource is expected to decline; much of the controversy and uncertainty expressed over the gas supply outlook concerns the range of optimism about the rate of decline and the associated wellhead prices." from Policy Implications of the 1988 GRI Baseline Projection of U.S. Energy Supply and Demand to 2010", from GRI Insights, Gas Research Institute, Chicago, IL, December, 1988, p.6

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- 19 Chemical Marketing Reporter, May 16, 1988, Vol. 233, No. 20, p.4.
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PARTICULATE EMISSIONS -- 1991 EPA STANDARDSEPA Transit Bus Engine Emission Standards (g/BHP--hr)

	HC	CO	NOx	PM
Current Engines	0.5 to 1.0	1 to 5	5 to 9	0.4 to 0.8
1988-1990 Standard	1.3	15.5	6.0	0.6
1991 & Later Standard	1.3	15.5	5.0	0.1

HC=hydrocarbons, CO=carbon monoxide, NOx= nitrogen oxides, PM= particulate matter

g/BHP--hr= grams per brake-horsepower per hour

Fuel Comparison

	HC	CO	NOx	PM
1991 & Later Standard	1.3	15.5	5.0	0.1
CNG				
GM 454--Four Stroke	1.2	10.6	1.4	.02
Cummins L10 Four Stroke	1.3		4.5	.06
Iveco--Two Stroke	(less than DDC diesel)		14.4-16.91	.01

According to manufacturers, a CNG powered two stroke engine will not be available to meet 1991 standards due to high NOx levels. Two stroke engines are preferable to four stroke engines because they provide the "torque", or propulsion that buses need.

Methanol

	HC	CO	NOx	PM
DDC--6V92A Two Stroke	1-1.5	2-3	1.6-2.5	.08-.11
MAN-Four Stroke	(less than DDC diesel)		4.3-6.8	.02

Detroit Diesel anticipates having its 6V92A engine ready to meet 1991 standards. However this was tested with 100% Methanol. The engine does not meet the 1991 HC standards with Methanol 85, a mixture of 85% methanol and 15% gasoline. Methanol 85 is considered a fuel source more likely to gain widespread use because it eliminates the cold start problems associated with 100% Methanol.

The MAN four stroke engine was tested with both Methanol 85 and 100.

Ethanol

	HC	CO	NOx	PM
Ethanol/Diesel Injection System	(less than DDC diesel)		2.5-3.0	.08
100% Ethanol	(less than DDC 2 stroke methanol)			

The Ethanol injection system uses a mixture of 25% ethanol, 75% diesel and involves a retrofit of Des Moines, Iowa diesel bus fleet by Midwest Power Concepts. This system will meet the 1991 emission standards (Warren Dobbertin, Midwest Power Concepts, 7/24/89). At this time a separate ethanol engine has not been developed. However, Detroit Diesel has tested its two stroke methanol engines with ethanol (Rich Windsor, Detroit Diesel Corporation, 7/29/89). The emissions results are lower than the methanol.

Particulate Traps

Using a 1982 Detroit Diesel engine, 6V92 TA mechanically governed engine trap system, Detroit Diesel has been able to meet the 1991 regulations. However, two main hurdles, durability (continual regeneration) and reliability remain. A more likely scenario is that traps will be ready in 1994.

Aldehyde Emissions

All aldehydes are not regulated it is likely that they will be in the future. The following breakdown is as follows:

	Formaldehyde (in g/bhp/hr)	Total Aldehydes
Diesel	.05	.1
Methanol	.1-1.5	.1-1.5
CNG	not measured	

Aldehyde emissions are highest at idle, a particular problem for transit buses.

	HC	CO	NOx	PM
Particulate Traps	.03	1.5	4.4	.07

Emissions Requirements Contained in the Administration's Clean Air Proposal:

	HC	CO	NOx	PM
Current Engines	0.5 to 1.0	1 to 5	5 to 9	0.4 to 0.8
1988-1993 Standard	1.3	15.5	6.0	0.6
1994 & Later Standard	1.3	15.5	5.0	0.1

The Administration's Clean Air proposal delays implementation of the new emissions standards until 1994. But it does require a mandatory phasing in of alternative fueled vehicles beginning with model year 1991. If this proposal is adopted it would increase the likelihood that more engines would be available for 1991.

COMPARISON OF FUEL PRICES FOR THE CHICAGO REGION JUNE-JULY 1989

	<u>Price Per Gallon</u>	<u>BTU'S Per Gallon</u>	<u>Energy Equivalent Ratio to Diesel</u>	<u>Energy Equivalent Price</u>
Diesel	\$0.48	130,000	1	\$0.48
Methanol	\$0.50	57,000	2.28	\$1.14
Ethanol	\$1.15	76,000	1.71	\$1.97

	<u>Price Per Therm</u>	<u>Energy Equivalent Ratio to Diesel</u>	<u>Energy Equivalent Price</u>
Compressed Natural Gas:			
Optimistic Estimate	\$0.26	1.38	\$0.36
Regulated	\$0.40	1.73	\$0.69

Sources:

1. Diesel Price - CTA Operating Data, 3rd period ending 4/1/89.
2. Methanol Price - Ray Lewis, Methanol Corporation, 7/25/89.
3. Ethanol Price - Chicago area month of June, Rodney Weinsierl, Illinois Corn Growers Association, 7/24/89.
4. Compressed Natural Gas Price - Bob Anderson, Peoples Gas, 9/14/89.
5. BTU Data - Rich Windsor, Detroit Diesel Corporation, 7/27/89; Bill Sheppard, Battelle Institute, 8/21/89.

NOTES: Lower heating values are used because they correspond better to engine performance. Bill Sheppard, Battelle Institute, 8/21/89. Actual test of methanol engines in Seattle produced 46,000 BTU's of thermal efficiency.

**CAPITAL COST ESTIMATE FOR CTA AND PACE
CONVERSION TO COMPRESSED NATURAL GAS
(In Thousands of Constant Dollars)**

	TOTAL COST
CTA	
Garage Conversion*	\$56,122.8
Rolling Stock	
New Buses	2247
Additional Cost	\$33,705.0
Total	\$89,827.8
 Pace	
Garage Conversion* #	\$27,101.3
Rolling Stock	
New Buses	496
Additional Cost	\$7,440.0
Total	\$34,541.3
 Regional Total	
Garage Conversion*	\$83,224.2
Rolling Stock	\$41,145.0
TOTAL	\$124,369.2

* Assuming no additional land is required for outdoor fueling.
Rolling stock includes Pace fixed route buses, paratransit vans are not included.

Assumes a combination of slow and fast fill method for Pace buses.

CAPITAL COST ESTIMATE FOR CTA AND PACE
CONVERSION TO COMPRESSED NATURAL GAS

<u>CTA GARAGE CONVERSIONS</u> (Constant dollars)				
	No. of Fueling Stations	Total Square Feet	Fleet Size (Active Fleet)	Total Cost
Forest Glen	4	64,000	239	\$5,988,043
Kedzie	4	310,000	232	\$7,241,304
Archer Avenue	3	225,000	211	\$6,175,543
69th Street	4	129,000	235	\$5,705,978
North Park	4	78,000	288	\$5,456,522
Limits	3	134,000	135	\$6,330,435
Lawndale	3	148,000	111	\$5,798,913
77th Street	4	39,000	250	\$5,915,761
103rd Street	4	365,000	200	\$7,510,326

<u>PACE GARAGE CONVERSIONS</u>						
	No. of Fueling Stations (Slow Fill)	No. of Fueling Stations (Fast Fill)	Total Square Feet	Fleet Size	Optimistic Slow Fill Only	Conservative Slow/Fast Fill
Elgin DOT	1		63,000	27	\$1,128,152	\$2,283,152
Aurora	1		22,000	25	927,609	2,082,609
Joliet MTD	1		54,000	38	1,084,130	2,239,130
Pace North Division	1		52,000	35	1,074,348	2,229,348
Pace West Division	3	1	225,000	98	2,560,543	5,075,543
Pace Southwest Division	1		35,000	37	991,196	2,146,196
Pace South Division	3	1	190,000	91	2,389,348	4,904,348
Nortran	4	1	23,300	127	933,967	4,088,967
Wilbus	1		15,750	18	897,038	2,052,038
	16	3	680,050	496	\$11,986,331	\$27,101,332

FLEETS
(in thousands of constant dollars)

	<u>Cost Per Bus*</u>	<u>Cyclic Replacement</u>	<u>Annual Cost</u>	<u>Total Fleet Size</u>	<u>Total Replacement Cost</u>	<u>Diesel Cost</u>	<u>Total Replacement Cost</u>	<u>Additional Cost for Alternative Fuels</u>
CTA	\$215.0	187	\$40,258.8	2,247	\$483,105.0	\$200.0	\$449,400.0	\$33,705.0
Pace	\$215.0	41	\$8,886.0	496	\$106,640.0	\$200.0	\$99,200.0	\$7,440.0
TOTAL		229	\$49,144.7	2,743	\$589,745.0	\$200.0	\$548,600.0	\$41,145.0

Rolling stock includes Pace fixed route buses; paratransit vans are not included.

CAPITAL COST ESTIMATES FOR CTA AND PACE CONVERSION TO COMPRESSED NATURAL GAS

GARAGE CONVERSIONS

Garage conversion costs are divided into three sections, costs that are proportional to:

1. Number of fueling stations
2. Garage size
3. Fleet size

All estimates are in constant dollars.

FUELING STATION AND FLEET COSTS#

- #See Peoples Gas Estimates (attached) for the CTA.
- Assume \$320,000 slow fill method for every 30 Pace buses.
- Assume \$1,000,000 for each fast fill compressor for every Pace garage with 90 or more buses.

GARAGE COSTS (Estimates are proportional to 460,000 sq.ft.)

HVAC	
Ventilation and heating	\$1,000,000
Equipment	240,000
Miscellaneous	120,000
Fire Protection Systems	690,000
Environmental Protection	<u>75,000</u>
Sub-total	\$2,125,000
TOTAL	\$2,125,000 *

- * Does not include costs related to fleet size or number of fueling stations.

NOTES:

- Based on garage conversion estimates by J. McCormick, SEPTA, to convert one half of a 230,000 sq.ft. garage.
- Assumes that no additional land is required for outdoor fueling.
- Assumes no additional rolling stock.

PROPOSED CTA CNG CAPITAL COST
1:1 EFFICIENCY RATIO

A	B	C	D	E	F	G	H	I	J	K	
Buses Asgn.	Buses in Service	Daily Usage (gal)	Daily CNG Usage (acf)	Average Usage (gal/bus)	Average Usage (cf/bus)	Comp Cap Req'd per Lane (cfa)	# Fill Lanes Req'd	Comp Cap Req'd per Site (cfa)	# Comp 2,000 cfa (incl. spare)	Cost	
103rd	241	300	8,800	1,182	44	5,912	1,971	4	7,883	4	\$2,600,000
77th	297	250	12,000	1,612	48	6,450	2,150	5	10,750	4	\$2,600,000
69th	267	235	9,600	1,290	41	5,489	1,830	4	7,319	4	\$2,600,000
Archer	241	311	7,500	1,008	36	4,776	1,592	4	6,368	3	\$1,950,000
Kedzie	269	232	9,000	1,209	39	5,213	1,738	4	6,950	4	\$2,600,000
Lawndale	138	111	5,200	699	47	5,295	2,098	2	4,197	3	\$1,950,000
Limits	152	135	4,900	658	36	4,877	1,626	2	3,251	3	\$2,400,000
North Park	336	288	9,000	1,209	31	4,199	1,400	6	8,398	4	\$2,600,000
Forest Glen	279	239	9,600	1,290	40	5,397	1,799	4	7,196	4	\$3,200,000
Total	2,220	1,901	75,600	10,158	40	5,344	35		33		\$22,500,000

PROPOSED CTA CNG CAPITAL COST **1:1 EFFICIENCY RATIO**

Assumptions:

3 minutes to fill
 2 minutes to move
 5 minute fueling cycle per bus per lane
 5 hour maximum fill time per site
 138,000 BTU Natural Gas = 1 equivalent gallon diesel
 17 psi supply pressure at Limites and Forest Glen - \$800,000 per compressor
 125 psi supply pressure at all other locations - \$650,000 per compressor

Calculations:

A - Given by CTA
 B - Given by CTA
 C - Given by CTA
 D - Gallon Diesel x BTU/Gal x 1 Therm/100,000 BTU x 97.37 cu ft/therm
 E - Daily Usage (diesel gallons) / Buses in Service
 F - Daily Usage (CNG) / Buses in Service
 G - Average Usage / 3 (assumed fill time)
 H - Number of fill lanes required to meet assumed maximum fill time per site
 I - Compressor capacity required per lane / lanes required
 J - Number of 2,000 cfm compressors required to supply required capacity
 K - Number of compressors x cost per compressor

In developing background information for our study, we spoke to a variety of CNG design engineers throughout North America. One of the first things we discovered was that a 2 minute CNG refueling was unrealistic from the fluid mechanics standpoint. We, therefore, increased fueling time to 3 minutes for a total of a 5 minute fueling interval. With this extra minute, we were still able to complete refueling in about 5 hours at each site.

The number of refueling islands was kept the same at most locations. However, at a few sites it was necessary to add a fill island in order to maintain a 5 hour site refueling time.

Space availability varied at each site. Considering that each refueling station needed a pad 24' x 40' or 960 sq.ft., a large area would be required at multiple station locales. The older depots usually had limited room, i.e., Ashland Avenue facility.

Natural gas pressure of 125 psi was available at six of the nine depots. This lowered the originally estimated horsepower requirement and, therefore, the cost of the compressor.

Some values we were given needed clarification. Listed below are the numbers we were given versus what we found during our research.

	<u>Value Given</u>	<u>Actual Value</u>
CNG-Diesel Equivalent on BTU basis	2.36	1.38
Daily Fuel Consumption per bus	90-120	30-50
Number of active buses	2200	1900
	<u>1/1 BTU Option</u>	<u>1.25 BTU Option</u>
<u>Summary</u>		
Capital Cost for Refueling Stations	\$22,500,000	\$26,550,000
Installation	\$11,250,000	\$13,275,000
Maintenance Cost per year	\$240,000	\$300,000
Total Capital Cost and Maintenance	\$33,990,000	\$40,125,000
Operating Cost of Gas Per Year		
At 26¢ per therm, Rate 4, Rider 17	\$9,635,249	\$11,965,130
At 40¢ per therm, Rate 3	\$15,056,238	\$18,699,280

APPENDIX D
OPERATING COST ESTIMATES FOR CONVERSION TO ALTERNATIVE FUELS

BASELINE ESTIMATE -- DIESEL

DIESEL #2

CTA	23,417,000	\$0.48	\$11,240,160	\$0	\$107,433,000	\$0	\$118,673,160	\$0
Pace	4,492,000	\$0.48	\$2,156,160	\$0	\$14,013,497	\$0	\$16,169,657	\$0
Total	27,909,000	\$0.48	\$13,396,320	\$0	\$121,446,497	\$0	\$134,842,817	\$0

LOW SULPHUR DIESEL

CTA	23,417,000	\$0.53	\$12,411,010	\$1,170,850	\$107,433,000	\$0	\$119,844,010	\$1,170,850
Pace	4,492,000	\$0.53	\$2,380,760	\$224,600	\$14,013,497	\$0	\$16,394,257	\$224,600
Total	27,909,000	\$0.53	\$14,791,770	\$1,395,450	\$121,446,497	\$0	\$136,238,267	\$1,395,450

METHANOL

CTA	23,417,000	\$1.14	\$26,695,380	\$15,455,220	\$132,434,490	\$25,001,490	\$159,129,870	\$40,456,710
Pace	4,492,000	\$1.14	\$5,120,880	\$2,964,720	\$17,719,825	\$3,706,328	\$22,840,705	\$6,671,048
Total	27,909,000	\$1.14	\$31,816,260	\$18,419,940	\$150,154,315	\$28,707,818	\$181,970,575	\$47,127,758

CNG

Optimistic

CTA	23,417,000	\$0.36	\$8,430,120	(\$2,810,040)	\$132,434,490	\$25,001,490	\$140,864,610	\$22,191,450
Pace	4,492,000	\$0.36	\$1,617,120	(\$539,040)	\$17,719,825	\$3,706,328	\$19,336,945	\$3,167,288
Total	27,909,000	\$0.36	\$10,047,240	(\$3,349,080)	\$150,154,315	\$28,707,818	\$160,201,555	\$25,358,738

APPENDIX D
OPERATING COST ESTIMATES FOR CONVERSION TO ALTERNATIVE FUELS

Gallons per Year	Price Per Gal. (\$\$)*	Total Fuel Cost	Additional Fuel Cost	Total Main. Costs	Additional Main. Costs	Total Operating Costs	Additional Operating Costs
Conservative							
CTA	\$0.69	\$16,157,730	\$4,917,570	\$132,434,490	\$25,001,490	\$148,592,220	\$29,919,060
Pace	\$0.69	\$3,099,480	\$943,320	\$17,719,825	\$3,706,328	\$20,819,305	\$4,649,648
Total	\$0.69	\$19,257,210	\$5,860,890	\$150,154,315	\$28,707,818	\$169,411,525	\$34,568,708
ETHANOL							
CTA	\$1.97	\$46,131,490	\$34,891,330	N/A	N/A	N/A	N/A
Pace	\$1.97	\$8,849,240	\$6,693,080	N/A	N/A	N/A	N/A
Total	\$1.97	\$54,980,730	\$41,584,410	N/A	N/A	N/A	N/A

NOTES:

*All fuel prices are expressed in energy equivalent units, i.e., the price of the energy equivalent to one gallon of diesel.

Methanol maintenance estimates based on Seattle Metro operating experience, (Conversation with Jim Boone, 9/5/89)
Due to lack of available estimates, CNG estimate assumes similar maintenance expense as methanol

Pace private carrier capital cost will be passed onto Pace as an operating expense. The above estimates do not include any operating expense for Pace private carriers.

CAPITAL COST ESTIMATE FOR CTA AND PACE CONVERSION TO METHANOL

(in thousands of constant dollars)

	<u>TOTAL COST</u>
CTA	
Garage Conversion*	\$75,554.2
Rolling Stock	
New Buses	2247
Additional Cost	\$44,940.0
TOTAL	\$120,494.2
Pace	
Garage Conversion*	\$24,366.3
Rolling Stock	
New Buses	496
Additional Cost	\$9,920.0
TOTAL	\$34,286.3
Regional Total	
Garage Conversion*	\$99,920.5
Rolling Stock	\$54,860.0
TOTAL	\$154,780.5

* Assumes no additional land is required for outdoor fueling.
Rolling stock includes Pace fixed route buses, paratransit vans are not included.

**CAPITAL COST ESTIMATE FOR CTA AND PACE
CONVERSION TO METHANOL
(Garage Conversions)**

Garage conversion costs are divided into three sections, costs that are proportional to:

1. Number of fueling stations
2. Garage size
3. Fleet size

All estimates are in constant dollars.

FUELING STATION COSTS (Estimates are for one fueling station)

Conversion of Facility - Separate Fuel Building	\$278,280
Fuel Dispensing	67,960
HVAC - Ventilation (fans & pits)	106,000
Electrical Systems	222,500
Equipment	157,000
Fire Protection Systems (fuel area sprinklers)	<u>35,000</u>
Subtotal	\$866,740

GARAGE COSTS (Estimates are proportional to 460,000 sq.ft.)

HVAC - CTA Facility	\$1,000,000
HVAC - Pace Facility	500,000
Miscellaneous	117,000
Fire Protection System (fire extinguishers)	21,420
Environmental Protection	398,250
Subtotal (per CTA facility)	\$2,036,670

FLEET COSTS# (Estimates are for a fleet of 110 buses)

Conversion of Facility (tanks and installation)	\$223,858
HVAC (roof/fume ventilation)	1,690,500
Fire Protection Systems (maintenance and storage areas)	409,570
Subtotal	\$2,323,928

Does not include new rolling stock.

NOTES: Based on garage conversion estimates by J. McCormick, SEPTA, to convert one half of a 230,000 sq.ft. garage.

Assumes that no additional land is required for outdoor fueling.

**CAPITAL COST ESTIMATE FOR CTA AND PACE
CONVERSION TO METHANOL
SERVICE BOARD GARAGE CONVERSION ESTIMATES**

CTA Garage Conversions @ (Constant Dollars)

	<u>Number of Fueling Stations</u>	<u>Total Square Feet</u>	<u>Fleet Size</u>	<u>Total Cost</u>
Forest Glen	2	64,000	277	\$8,734,887
Kedzie	2	310,000	278	\$9,330,018
Archer Avenue	2	225,000	241	\$8,349,998
69th Street	2	129,000	263	\$8,590,782
North Park	3	78,000	341	\$10,986,398
Limits	1	134,000	157	\$5,496,288
Lawndale	1	148,000	140	\$5,169,802
77th Street	3	39,000	300	\$10,029,206
103rd Street	2	365,000	250	\$8,866,807
TOTAL	18	1,492,000	2,247	\$75,554,186

Pace Garage Conversions @

Elgin DOT	1	63,000	27	\$2,084,160
Aurora	1	22,000	25	\$1,946,239
Joliet MTD	1	54,000	38	\$2,295,552
Pace North Div.	1	52,000	35	\$2,227,506
Pace West Div.	1	225,000	98	\$3,962,152
Pace SW Div.	1	35,000	37	\$2,230,092
Pace South Div.	1	190,000	91	\$3,732,598
NORTRAN	1	23,300	127	\$4,104,188
WILBUS	1	15,750	18	\$1,783,769
TOTAL	9	680,050	496	\$24,366,256

@ Assumes no gas fired heaters

CAPITAL COST ESTIMATE FOR CTA AND PACE CONVERSION TO METHANOL

		<u>FLEETS</u>					(in thousands of constant dollars)	
	<u>Cost Per Bus*</u>	<u>Cyclic Replacement</u>	<u>Annual Cost</u>	<u>Total Fleet Size</u>	<u>Total Replacement Cost</u>	<u>Diesel Cost</u>	<u>Total Replacement Cost</u>	<u>Additional Cost for Alternative Fuels</u>
CTA	\$220.0	187	\$41,195.0	2,247	\$494,340.0	\$200.0	\$449,400.0	\$44,940.0
Pace	\$220.0	41	\$9,092.6	496	\$109,120.0	\$200.0	\$99,200.0	\$9,920.0
TOTAL		229	\$50,287.6	2,743	\$603,460.0	\$200.0	\$548,600.0	\$54,860.0

* Assume base bus cost of \$200,000 and \$20,000 for addition of Methanol.
(Detroit Diesel estimate per David Feely, New York City TA 12/8/89)

8/11/2008

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